Association of three species of *Strymon* Hübner (Lycaenidae: Theclinae: Eumaeini) with bromeliads in southern Brazil

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Abstract. As part of a project studying the species richness of bromeliad flower visitors and the diversity and nature of their animal-plant interactions, three species of the lycaenid butterfly genus *Strymon* were recorded as pests of bromeliad inflorescences. *Strymon ziba* fed on the fruits of *Aechmea nudicaulis*, *S. oreala* on those of *Ae. lindenii* and *Ae. caudata* and *S. serapio* on the dry capsules of *Vriesea friburgensis*. The caterpillars of *S. ziba* and *S. oreala*, pests of cultivated pineapple, were facultatively associated with ants. One *S. ziba* pupa was parasitized by a chalcidid wasp. One *S. oreala* pupa was parasitized by an ichneumonid wasp. Behaviour and life history data of the caterpillars are described and aspects of the host specificity of the lycaenids and potential pest control by parasitoid wasps are discussed.

Key words: *Aechmea*, animal-plant interactions, Atlantic rain forest, Bromeliaceae, Chalcididae, herbivory, Ichneumonidae, parasitism, restinga, *Vriesea*.

Introduction

Bromeliaceae, a neotropical plant family, can be considered keystone species by providing microcosms for the richness of tropical rain forests due to the high diversity of animal taxa, especially arthropods, associated with them (Frank & Lounibos, 2008). Among the latter, Lepidoptera are major herbivores with many caterpillars feeding upon bromeliad foliage: *Napaea eucharilla* Bates (Riodinidae) on *Werauhia sanguinolenta* (Cogniaux & Marchal) J. R. Grant (syn. *Vriesea sanguinolenta*, Schmidt & Zotz 2000), *Aechmea bracteata* Grisebach, *Ae. nudicaulis* (L.) Grisebach (Beutelspacher, 1972) and *Ananas comosus* (L.) Merrill (Schmidt & Zotz, 2000), *Caria domitianus ino* Fabricius (1793) (Riodinidae) on *Tillandsia caput-medusae* E. Morren (Beutelspacher, 1972; Frank & Lounibos, 2008), *Dynastor darius darius* Stichel and *D. macrosiris* Westwood (Nymphalidae, Urich & Emmel, 1991a, b) on *Ae. nudicaulis* and *Castnia boisduvalii* Walker (Castniidae, Biezanko, 1961; Frank & Lounibos, 2008) on *T. aeranthos* (Loiseleur) L. B. Smith. Beutelspacher (1972) also mentioned *Thecla hesperitis* Butler & Druce 1872 (Lycaenidae), which is a mistaken record of *Ziegleria hesperitis*, feeding on *Tillandsia caput-medusae*, but voucher specimens of "*Thecla hesperitis*" in UNAM (Universidad Nacional Autónoma de Mexico) examined by Robert K. Robbins are in fact *S. serapio* Godman & Salvin (1887) (R. K. Robbins, pers. comm.). Not only the plants' vegetative parts, but also their inflorescences contribute significantly to the local faunal biodiversity by providing resources for a great variety of flower visitors that act as pollinators or pollen and nectar robbers (Sazima & Sazima, 1999; Machado & Semir, 2006; Canela & Sazima, 2003; Schmid *et al.*, b, submitted). In addition to causing leaf damage, some herbivorous arthropods associated with bromeliad inflorescences directly interfere with plant reproduction by feeding on reproductive tissues of flowers and fruits, like beetles, butterflies and moths, grasshoppers and even crabs (Fischer *et al.*, 1997; Canela & Sazima, 2003; Frank & Lounibos, 2008). An example of inconspicuous herbivory affecting plant reproductive success was observed in the bromeliads *Vriesea friburgensis* Mez and *Werauhia gladioliflora* (H. Wendland) J. R. Grant whose buds are parasitized by *Eurytoma* wasps (Hymenoptera, Eurytomidae) so no fruits are formed (Gates & Cascante-Marín, 2004; Grohme *et al.*, 2007). Beyond that, cases of seed predation by *Cholus* and *Metamasius* weevils (Coleoptera, Curculionidae) (Frank 1999) and *Epimorius testaceellus* Ragonot 1887 (Pyralidae) larvae that develop in flower pods of *Tillandsia fasciculata* Swartz (1788) (Bugbee, 1975; Heppner, 1992) have been reported. New World hairstreaks (genus *Strymon*, Lycaenidae: Theclinae: Eumaeini) use ornamental bromeliads (genera *Aechmea*, *Tillandsia*) and the commercial pineapple (*Ananas comosus*) as host plants

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(Robbins & Nicolay, 2002). *Strymon megarus* Godart 1824 (syn. *Thecla basilides*, also misspelled as *T. basalides*) larvae feed on *Ananas* and other bromeliads like *Ae. bracteata* (Beutelspacher, 1972; Frank & Lounibos, 2008) and can be considered pest species. *Strymon ziba*, *S. serapio* (Robbins & Nicolay, 2002) and *S. oreala* (Zikán, 1956), the species examined in our study, were reported to eat bromeliads, *S. ziba* Hewitson 1868 and *S. oreala* Hewitson 1868 are known pests of *A. comosus* (Harris, 1927; Zikán, 1956). Since caterpillars and other immature stages of the Eumaeini are small and cryptically coloured, food plants have been recorded for only 25% of the species (Duarte *et al.*, 2005).

Studying the species richness of bromeliad flower visitors and the diversity and nature of their animal-plant interactions in the Atlantic rain forest of southern Brazil, we found lycaenid caterpillars attacking developing fruits. In order to assess the specificity of these associations we examined inflorescences of four common sympatric bromeliad species, *Aechmea nudicaulis*, *Ae. lindenii* (E. Morren) Baker, *Ae. caudata* Lindman 1891 (Bromelioideae) and *Vriesea friburgensis* (Tillandsioideae), for the presence of larvae and reared them for identification. We also recorded basic data on development, behaviour and natural enemies of the caterpillars.

Materials and methods

Bromeliads with inflorescences were searched for eggs and larvae between November 2006 and June 2008 at four study sites (frost-free subtropical habitats): Santo Antônio de Lisboa and the Environmental Conservation Unit Desterro UCAD (both secondary forest; 27°30'26" S, 48°30'28" W; 27°31'50" S, 48°30'50" W) (Zillikens *et al.*, 2001; Zillikens & Steiner, 2004) as well as Joaquina Beach and Campeche Beach (dune vegetation, Sampaio *et al.*, 2002; 27°40'38" S, 48°28'48" W; 27°37'37" S, 48°26'59" W), on Santa Catarina Island, southern Brazil. All bromeliads examined were growing terrestrially although *Aechmea nudicaulis* also occurs on trees. In total, 20 infested bromeliads of four species (*Aechmea nudicaulis*, n = 11; *Ae. lindenii*, n = 2; *Ae. caudata*, n = 5; and *Vriesea friburgensis*, n = 2), growing terrestrially on rocks, in sand or shallow soil, were taken to the laboratory. Presence, size and colour of eggs and caterpillars on the inflorescences were observed regularly every 1-2 days. Ants associated with lycaenid larvae were also collected. When larvae had finished feeding and retreated for pupation, the bromeliad plants were enclosed with fine gauze to capture the emerging adult butterflies.

Voucher specimens of the recorded butterfly, ant and parasitoid species were deposited in the entomological collection of J. Steiner at the Native Bee Laboratory (LANUFSC), BEG, Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil.

Results

Three lycaenid species of the genus *Strymon* were reared from the caterpillars found on four bromeliad species. All constitute new records of parasite/host association. Up to four caterpillars were found simultaneously on one inflorescence.

Strymon ziba (Hewitson 1868)

We found 24 larvae of *S. ziba* on 11 inflorescences of the bromeliad *Aechmea nudicaulis*, yielding an average of 2.2 caterpillars per inflorescence (range 1-4) from November 2006 to January 2007. Seventeen adults emerged in the laboratory, overall sex ratio was 0.7 (M/F). On all inflorescences we detected small white spherical bodies, the eggs from which the larvae had hatched (Fig. 1A, B).

The colour of the larvae was cryptic and changed during their growth from whitish-yellow to reddish-pink (Fig. 1C, D). The former matched well to the fruits whereas the latter matched well to the inflorescence stem. The larvae appeared shortly after the end of the flowering period and stayed close to the ripening fruits. Larval feeding behaviour consisted of gnawing a hole into the fruit base large enough for the smaller larval stages to enter the fruit completely and for the larger stages to insert the head and anterior part into the cavity. Through this hole they fed on the soft nutritive tissues of the ovary and ovules, leaving the rigid cortical outer wall of the developing fruit mostly intact (Fig. 1A, B). On an inflorescence of *Ae. nudicaulis* with two larvae feeding, 30 fruits were damaged, resulting in a mean of 15 fruits damaged per larva. Mean fruit loss per inflorescence was 84.5% (n = 2). Occasionally, the larvae drew back from the fruits to hide under the bracts for about half a day, probably for moulting.

Development in the egg took five days (n = 2). The larval phase lasted 13-15 days (n = 1). The fully grown larvae (≈12-15 mm length) moved into the bromeliad rosette where they pupated on the upper side of the leaves half way between tip and base; one male pupated on a bract of the inflorescence. Pupation took 8-11 days (n = 3). Imagines (Fig. 1E) emerged between mid November until end of January, synchronized to the flowering/fruiting period of *Ae. nudicaulis*.

In the laboratory, caterpillars were occasionally

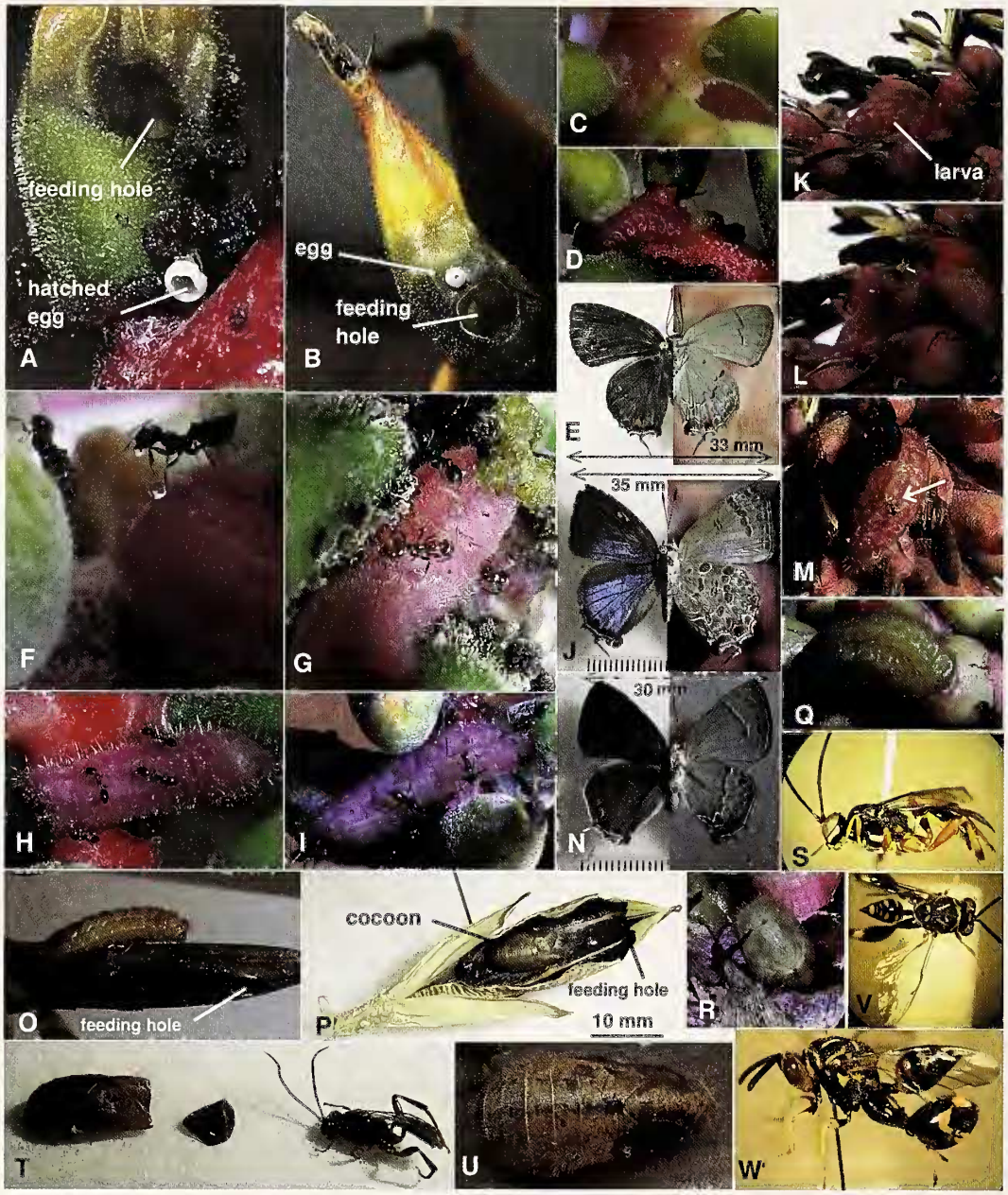

Figure 1. *Strymon* larvae on bromeliads on Santa Catarina Island, Southern Brazil.
A-P: *Strymon* larvae and imagines and associated ants
A-B: Infested fruits of *Aechmea nudicaulis*, Santa Catarina Island, Brazil. **A**: Fruit with feeding hole and larval faeces of *Strymon* caterpillar and a hatched egg of *Strymon ziba* at the base of the fruit. **B**: Fruit with feeding hole and a closed egg. **C-D**: Colour change in *Strymon ziba* larvae. **C**: Small, whitish-yellow. **D**: Larger larva after colour change to reddish-pink. **E**: *Strymon ziba* female, collected on *Aechmea nudicaulis*, Santa Catarina Island, Brazil. Right-hand side ventral view, left-hand side dorsal view. **F-I**: Ants associated with *Strymon ziba* caterpillars. **F**: *Crematogaster limata*. **G**: *Linepithema iniquum*. **H**: *Monomorium* sp. (*floricola*). **I**: *Paratrechina* sp. **J**: *Strymon oreala*, female, right-hand side ventral view, left-hand side dorsal view. **K**: *Strymon oreala* larva feeding on fruits of *Aechmea caudata*. **L**: Larva of *S. oreala* feeding on withered flower petals. **M**: *Tapinoma melanocephalum* ant on the back of a *S. oreala* larva (white arrow). **N**: *Strymon serapio*, female, right-hand side ventral view, left-hand side dorsal view. **O**: Larva of *S. serapio* on dry fruit of *Vriesea friburgensis* with feeding hole. **P**: Dry fruit of *Vriesea friburgensis* with exuvia of *S. serapio* inside. Length of exuvia: ≈ 12 mm.
Q-W: *Strymon* larvae at *A. lindenii* and parasitoids.
Q-R: *Strymon* larvae. **Q**: *Strymon* larva on *A. lindenii* feeding on fruit. **R**: *Strymon* pupa on infructescence.
S-T: *Anisobas*, a parasitoid of *Strymon* sp. **S**: Lateral view of the *Anisobas* imago that hatched from the *Strymon* exuvia. **T**: Opened *Strymon* exuvia besides hatched *Anisobas* imago. **U-W**: *Conura*, a parasitoid of *Strymon* sp. **U**: Opened pupal case of *Strymon* sp. **V**: Imago of *Conura* sp., dorsal view. **W**: Lateral view.

tended by ants of four species: *Crematogaster limata* Smith 1858, *Linepithema iniquum* Mayr 1870, *Monomorium floricola* Jerdon 1851 and *Paratrechina* sp. (Fig. 1F-I). Tending worker ants walked over the bodies of the caterpillars and took up small droplets secreted posterodorsally (Fig. 1F).

Additionally, we observed *S. ziba* imagines sucking extrafloral and floral nectar from inflorescences of *Ae. nudicaulis* and one female laying one single egg on each of two recently withered flowers, respectively. The female flew around the inflorescence and sucked nectar of several flowers before ovipositing. The initially greenish eggs turned white after a few minutes. Thereafter, the female left the inflorescence.

***Strymon oreala* (Hewitson 1868)**

We discovered seven larvae of *S. oreala* (Fig. 1J) on five inflorescences of the bromeliad *Ae. caudata* (April 2008) and two larvae on two inflorescences of *Ae. lindenii* (August – September 2007). As described for *S. ziba* on *Ae. nudicaulis* larvae fed on the developing fruits of *Ae. lindenii* and *Ae. caudata* (Fig. 1K-M) and retreated into the rosette for pupation. Additionally, a larva was seen feeding on withered flower leaves, probably eating old reproductive structures inside the petals (Fig. 1L). On an inflorescence of *Ae. caudata* with one larva feeding, 15 fruits were damaged. The pupal stage took 15-16 days (n = 4). The larvae were reddish-pink like the inflorescence stem (Fig. 1 K-M). Occasionally, single ants of the species *Tapinoma melanocephalum* Fabricius 1793 were observed on *S. oreala* larvae (Fig. 1M).

***Strymon serapio* (Godman & Salvin 1887)**

We detected four brownish-yellow larvae of *S. serapio* (Fig. 1N) on two inflorescences of the bromeliad *Vriesea friburgensis* in secondary forest in December 2007. The larvae chewed a hole into the hard capsule of the developing fruit (Fig. 1O) and fed on the seeds within. Pupation took place inside the empty fruit capsule (Fig. 1P), the imago emerged after 11 days (n = 1).

Parasitoids

On two occasions we found *Strymon* brood infested with a parasitoid. The first case (14 November 2005, Campeche Beach) was a larva on an inflorescence of *Ae. lindenii* (Fig. 1Q). Since the only identified *Strymon* infestation of this bromeliad was by *S. oreala* (see above) we assume that the parasitized larva belonged to the same species. The larva pupated on the infructescence on 18th November 2005 (Fig. 1R). This might, however, not be the usual location for pupating because Aurum® insect glue had been applied to the infructescence stem, thus preventing the caterpillar from moving down to the rosette. After 18 days an ichneumonid wasp of the genus *Anisobas* (subfamily Ichneumoninae) emerged from the pupa (Fig. 1S, T).

In the second case, discovered 6 January 2007 at Santo Antônio, a pupa (Fig. 1U) was located at the upper margin of a leaf of *Ae. nudicaulis* (plant with infructescence). So far, we found this bromeliad species only to be infested with *S. ziba* (see above); hence we assume that the pupa belonged to this species. On 23 January 2007, a chalcidid wasp of the genus *Conura* (subfamily Chalcidinae), "most probably of the *flava* group" (Gérard Delvare, pers. comm.), emerged from the pupa (Fig. 1V, W).

Discussion

Larval behaviour and host plants

Our findings constitute new host records for the associated *Strymon* species. The only lycaenids so far recorded on *Ae. lindenii* are larvae of an unidentified species of *Thecla* on Santa Catarina Island (Lenzi *et al.* 2006) with a similar feeding behaviour and life history data as described here for *S. oreala*. It is therefore possible that they did in fact observe larvae of a species of *Strymon*. Our observations also confirm some life history traits reported by Duarte *et al.* (2005) such as the cryptic coloration of the larvae which is well adapted to parts of the plants on which they move or feed. Besides the evident association of *Strymon* larvae with infructescences, they were even more selective in the sense that they fed only on the internal parts of the developing fruits, i.e. the ovaries, but not on leaves, sepals or other plant tissues. By hollowing out the fruits they create their own shelter for feeding or even pupal chambers (in case of *S. serapio*).

We further report here the first data on the life cycle of the three species, all of which develop within about one month and without diapause. It is therefore likely that the *Strymon* species studied by us are multivoltine having several generations per year. This is in agreement with the pattern reported for other *Strymon* species in the tropics (Opler *et al.* 2009). The choice of hosts by ovipositing females depends on seasonal availability of fruiting plants. The bromeliads studied by us all have relatively short and seasonal fruiting periods, so that only one or two generations can develop on a given plant population.

Adults emerging at the end of a flowering period have to seek for alternative hosts for egg laying. In our study, *Strymon oreala* was the only species recorded on two hosts both in the genus *Aechmea*. Interestingly, the inflorescences and flowers of *Ae. lindenii* and *Ae. caudata* are very similar in floral morphology and coloration (Kamke, pers. obs.), but *Aechmea lindenii* flowers from August to November (Dorneles *et al.*, ms) whereas *Ae. caudata* flowers from March to June without overlap, though single plants of both *Aechmea* species can be found flowering outside the main flowering period, for example *Ae. lindenii* on more open areas in restinga sites throughout the year (Lenzi *et al.* 2006) and *Ae. caudata* in secondary forest in September (Kamke, pers. obs.). Nevertheless, there is a gap of several months for which we do not yet know the host plants. We know, however, that *S. oreala* does not attack the infructescences of *Ae. nudicaulis* or *V. friburgensis*, which flower between. Therefore, a switch to another host, whether bromeliad or not, must occur in *S. oreala*, *S. serapio* and *S. ziba*.

As *S. ziba* and *S. oreala* are pests of cultivated pineapple it would be interesting to further identify alternative host plant species in order to better understand under which circumstances the larvae reach pest status and to assess their damage to the crop. In this context it is also worth emphasizing our record of a possible natural enemy of *S. ziba*, a parasitoid wasp of the family Chalcididae. Its potential as natural biological control agent should be assessed by elucidating its life history, abundance and host specificity.

Association with ants

As has been reported from other lycaenid caterpillars, the larvae of *S. ziba* possess a dorsal secretory organ, the Newcomer's gland (Malicky 1970), that might exude honey-like droplets to appease ants. Of the species recorded, *Monomorium floricola* and *Tapinoma melanocephalum* are invasive ants (Delabie *et al.* 1995; Campos-Farinha 2005) and only occurred in the laboratory. We consider the same to be true for *Paratrechina* sp. for this species was only observed in the laboratory. *Crematogaster limata* and *Linepithema iniquum*, however, were frequently found nesting in the bromeliads or visiting their inflorescences (Rosumek *et al.* 2008, Schmid *et al.* a, ms) and were thus brought to the laboratory together with the plants taken in the field. These two, at least, may be considered associated with the *Strymon* caterpillars under natural conditions, albeit only facultatively since larvae observed in the field were mostly not tended by ants.

Diversity of the *Strymon* – bromeliad association

Our finding that four species of bromeliads were parasitized in very similar ways by *Strymon* larvae is remarkable in yet another aspect. It confirms a relatively high diversity and abundance of sympatric, even syntopic, *Strymon* species in bromeliad-rich Atlantic forest and restinga habitats of southern Brazil. Thus, the fact that three co-occurring species were recorded in studies on only four bromeliad species suggests that a thorough examination of further bromeliad inflorescences might result in the finding of more *Strymon* species and underlines the importance of these plants for sustaining a high diversity of the lepidopteran fauna in the Mata Atlântica.

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